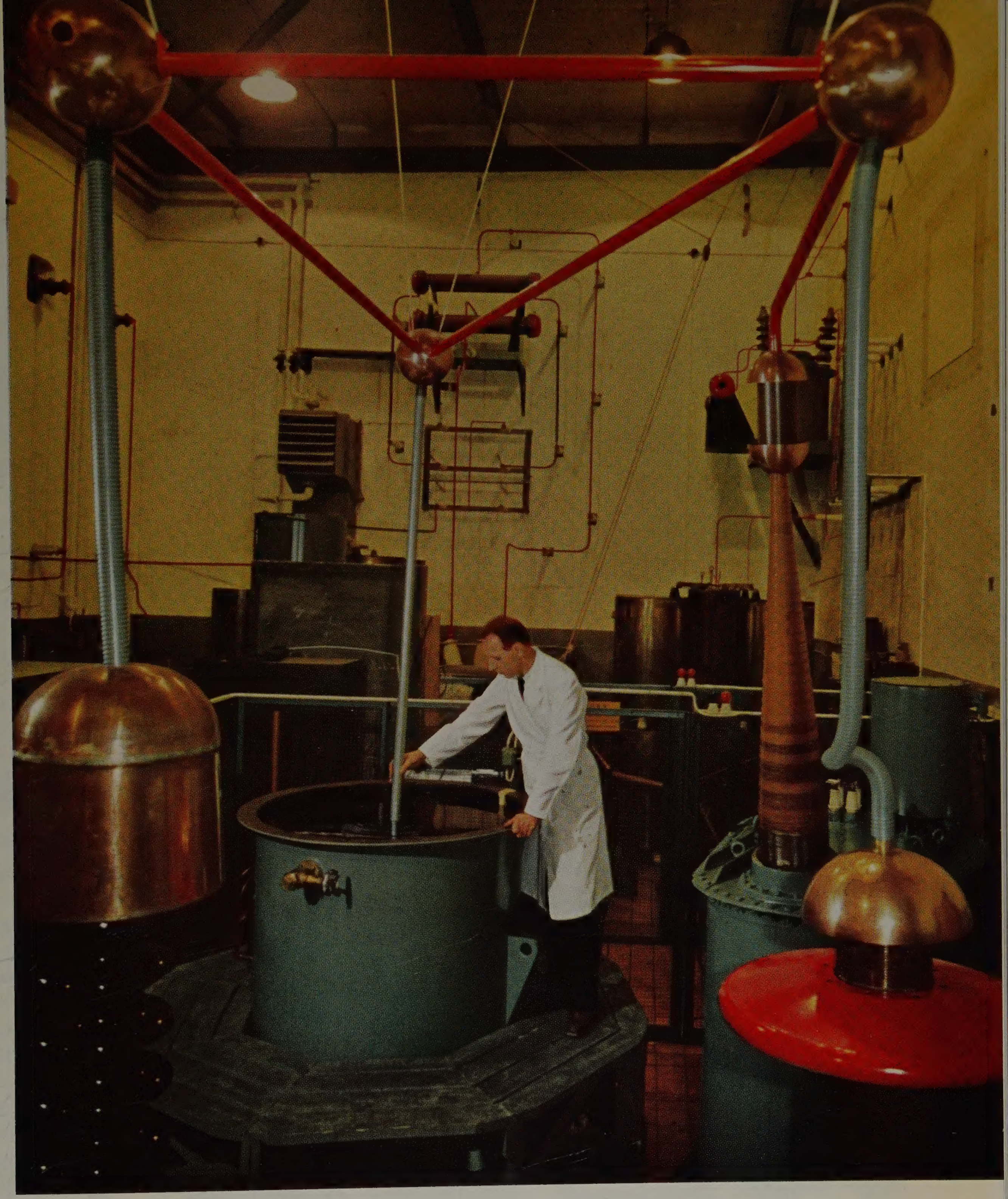

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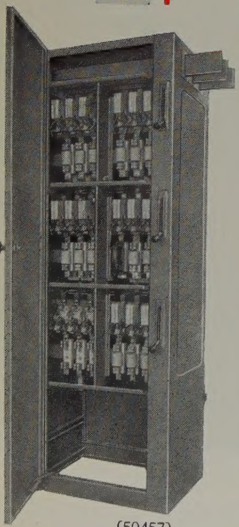
Test circuit for measuring corona in a test specimen submerged in oil, at the High-voltage Laboratory, Ludvika. (F 362. Photo Gullers)

everything under one roof



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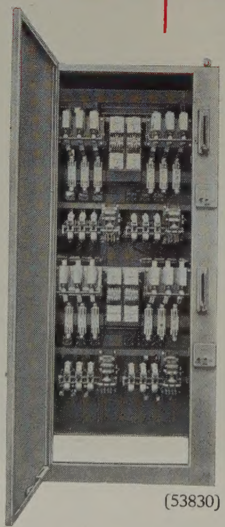

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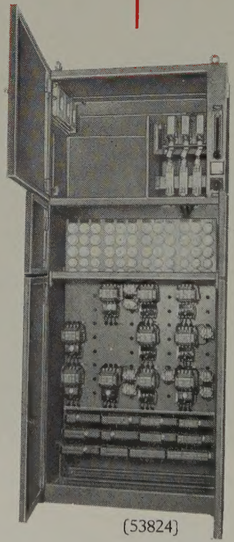

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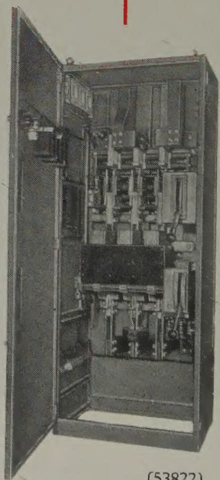

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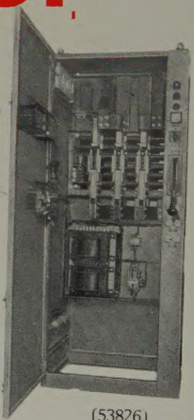

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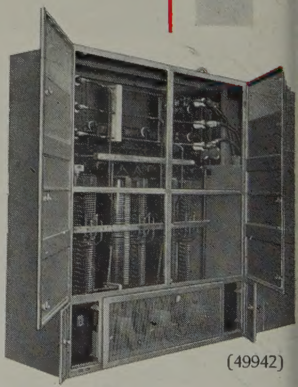

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HE RING TORDUCTOR – A TORQUE-GAUGE, VITHOUT SLIP RINGS, FOR INDUSTRIAL IEASUREMENT AND CONTROL

rvar Dahle, Research Laboratories, Electronics Department, Västerås

U.D.C. 621.317.49:531.78
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ıe paper describes a new, ring-shaped torque-gauge to stationarily mounted around the shaft with an air-gap the order of a tenth of an inch. The gauge measures e change in permeability of the shaft at 45° to the is, a change which is essentially proportional to the rque, and induces a proportionate output voltage that r a heavy shaft at normal mechanical loading is of the der of 10 volts over 10 kiloohms, sufficient to operate dicating and recording instruments without any ampli- ation.

IE PROBLEM

many industries there is a need for a robust torque- uge for rotating shafts, often of very large diameters. some cases it is a mere question of overload pro- ction; in other cases, e.g. in pulp-grinding, the problem mainly to keep the torque at a constant value. For ese two types of applications, the requirements in spect of calibration and linearity are not very stringent. many other cases there is, however, a requirement r a torque-meter that can be calibrated with reason- le precision, and if possible with a reasonably linear aracteristic. Such a torque-meter is of great value e.g. r the continuous measurement of the torque trans- tted to a ship's propeller or the torques transmitted the different spindles in a rolling mill.

all these cases robustness and insensitivity to dirt and oisture are of utmost importance, and from this point view slip rings are most undesirable. A high output wer and a not too high output impedance are on other hand essential in order to make the gauge in- nsitive not only to dirt and moisture, but also to stray lds from neighbouring power cables.

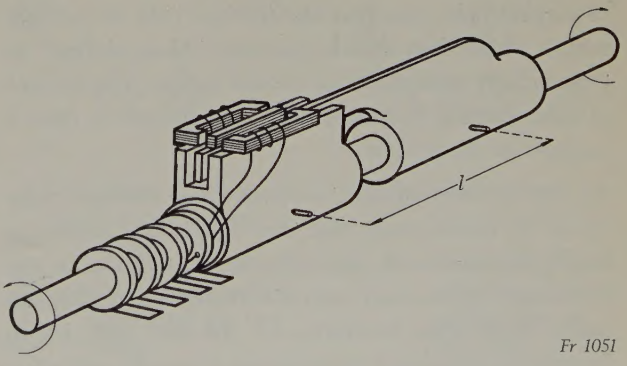
most industrial installations no reduction of the exist- shaft diameter is permissible and in many cases it is possible to insert a special calibrated measuring shaft, t the torque measurement has to be performed on the existing shaft to which the least possible modification should be made. In many cases only a rather short free length of a few inches is available.

For precision measurement, variations in voltage, frequency and temperature must not impair accuracy, and hysteresis should be negligible. This latter requirement is also essential for control purposes as any appreciable hysteresis could result in serious hunting. The torque-meter should also be independent of the rotational speed of the shaft, preferably down to zero r.p.m. so that calibration can be performed statically.

GAUGE PRINCIPLES TRIED FOR TORQUE-METERS

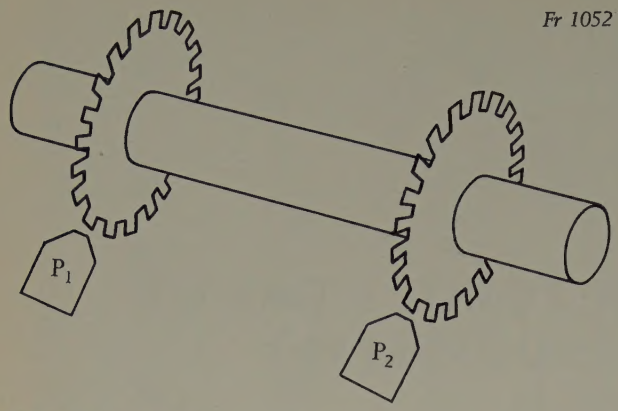
A great variety of gauge principles have been used for torque-meter design. Two different basic principles have been used, one involves measuring the torsion over a certain shaft length with some form of displacement gauge, the other is based upon direct measurement of stress or strain in a short section of the shaft.

The measurement of torsion for a certain shaft length can again be divided into two main groups. A representative of the first group is shown in Fig. 1. The torsion



l Measuring length

Fig. 1. Measurement of torsion for a certain shaft length l with displacement gauge and slip rings.



P₁–P₂ Pick-up heads

Fig. 2. Measurement of torsion for a certain shaft length without slip rings.

over the length *l* is here measured with a displacement gauge of the variable reluctance type, but a capacitive gauge has sometimes been used instead. One of the main disadvantages of this method is the relatively large axial space required. Normally there is also the big disadvantage of slip rings, but in some designs these have been eliminated, in one case by fitting the shaft with primary and secondary "rotating transformers", with one winding rotating and one stationary. In another design the displacement is measured by the change in resonance frequency of a string that is stretched by the torsion. This latter method is naturally hardly of use outside the laboratory.

To avoid these difficulties the angular displacement between the two sections of the shaft is sometimes measured as in Fig. 2. Two identical tooth-wheels are here fixed to the shaft at a certain distance from each other. A pick-up head of inductive, capacitive or photoelectric type is provided for each tooth-wheel and in this way two alternating voltages are produced, whose phase difference is a measure of the torsion and hence the torque.

Another method that has been used for measuring the torsion between the two tooth-wheels is to let a beam of parallel light rays pass the toothed rims of the two wheels which then shall be mutually "phase-shifted" so that no light comes through at zero torque. The amount of light passing, measured with a photocell, is then a measure of the torque.

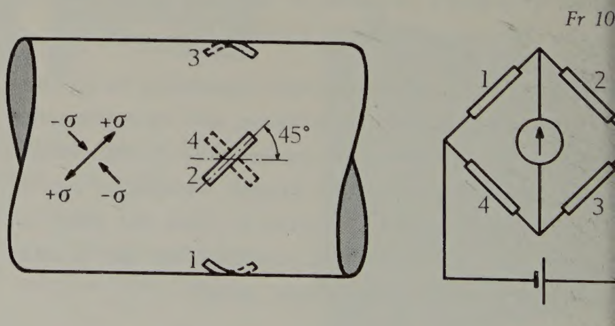
All the above-mentioned methods have amongst other things the disadvantage that they need a long measuring length. In some cases, especially in ships, this is no disadvantage, but in most cases the shafts are naturally not made longer than necessary, i.e. the free shaft length between bearing house and coupling is usually only a few inches, enough for insertion of screws in the coupling.

In these cases the only possibility is to use the other basic principle, mentioned at the beginning of this chapter, i.e. direct measurement of stress or strain in a sh section of the shaft. When torque is applied to a sh this gives rise to principal stresses at 45° to the a tensile stress in one 45° direction and compressive str in the other. The most widely used method is to meas these stresses by four strain gauges around the shaft indicated in Fig. 3. The necessary slip rings constit the main disadvantage.

Another method which directly measures the stress a short section is based upon the fact that the perm ability of steel is changed by stress. To measure t change an iron-mantled, stationary coil is placed arou the shaft. The change in inductance of this coil is us to determine the torque. For small torque values the i crease in permeability in the tensioned 45° direction however, of the same magnitude as the decrease in t compressed 45° direction, and the net change in lon tudinal permeability is thus zero for small torque valu giving zero sensitivity within this range. In order eliminate this disadvantage, the changes in permeabili in the 45° directions should instead be measured anal gously to the strain measurement at 45° in Fig. 3. Th is what is achieved with the torductor, which shall described in detail in the following chapters.

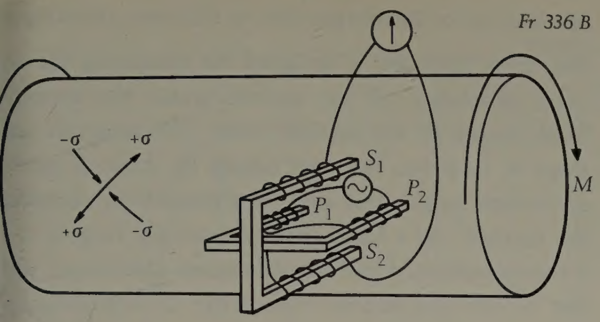
THE TORDUCTOR, A NEW TYPE OF TORQUEMETER

The torductor is a torque-gauge, primarily intended f heavy shafts. As already mentioned, the operating pri ciple is based upon the fact that the permeability of steel shaft is increased in one 45° direction and decrea ed in the other in proportion to the applied torque. Tw types of torductor have been developed, the cross to ductor and the ring torductor. The cross torductor the simplest version, introduced six years ago. Due some shortcomings of this device, a somewhat mo elaborate version, the ring torductor, has recently bee developed.



± σ Principal stresses
1–4 Strain gauges

Fig. 3. Measurement of strain in a short section of the shaft with strain gauges.



Principal stresses
Torque
P_1–P_2 Primary core
S_1–S_2 Secondary core

g. 4. The cross torductor principle for torque measurement.

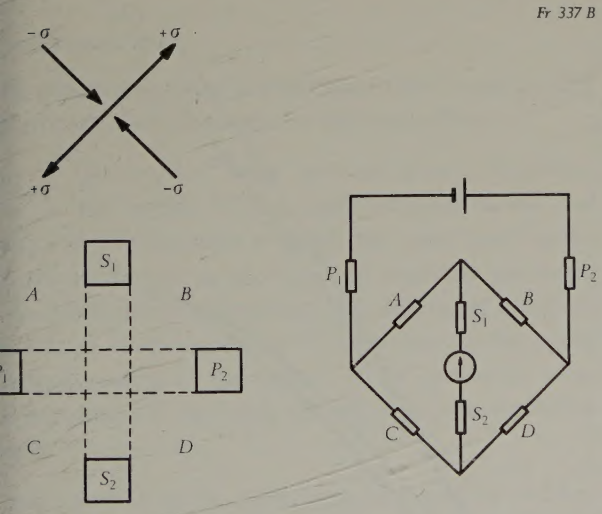
ne cross torductor will probably be superseded by the ng torductor for all torque-measuring purposes, but en so, a thorough description of the cross torductor nd its behaviour is not out of place as it will make sier an understanding of the ring torductor and suggest e motivation for the more complicated design of the tter.

HE CROSS TORDUCTOR

he principle

ne principle of the cross torductor is shown in Fig. 4. consists of two U-shaped, laminated iron-cores, equip- d with windings and mounted at right-angles to each her in a measuring head, which is placed adjacent to the shaft with one core parallel to the axis of the shaft and with an air-gap of a few millimetres (about a tenth of an inch) between the shaft and the poles of the two iron-cores. One core is magnetised with a.c., normally 50 or 60 c/s, and induces in the shaft surface a magnetic field which in the case of isotropy is symmetrical. Because of the symmetry, no flux passes through the other core at zero stress. However, the magnetic potential pattern is distorted by torque, resulting in a proportionate flux in the secondary core. The output is of the order of 1 volt over 50 kiloohms.

The method of operation is shown in more detail in Figs. 5a and b. Fig. 5a represents the shaft surface immediately in front of the cross torductor with the projection of the pole surfaces P_1, P_2, S_1 and S_2 indicated. *A* represents the reluctance of the magnetic field in the shaft surface between P_1 and S_1, *B* the reluctance between S_1 and P_2 etc. The four reluctances form a magnetic bridge which is completely analogous to an ordinary Wheatstone bridge. The corresponding electrical analogy is shown in Fig. 5b, where the battery corresponds to the exciting electromagnet $P_1 - P_2$ and the galvanometer corresponds to the secondary core $S_1 - S_2$. The resistances P_1, P_2, S_1 and S_2 in series with the battery and the galvanometer represent the corresponding air-gap reluctances. It is assumed that the shaft material is intrinsically isotropic. The reluctances *A, B,* C and *D* are then all of equal magnitude for an unloaded shaft and the magnetic bridge is thus completely balanced.



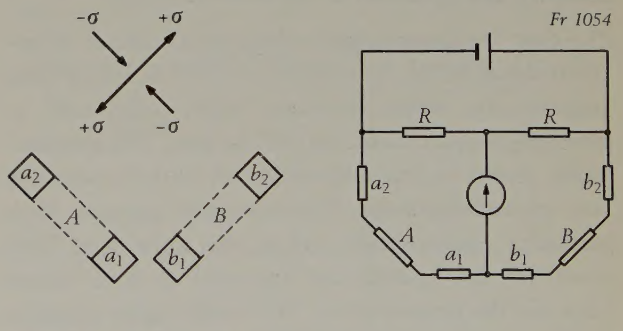
Reluctance bridge

b) Wheatstone bridge analogy

Principal stresses
-P_2 Air-gap reluctances for primary core
-S_2 Air-gap reluctances for secondary core

A, B, C, D Reluctances of magnetic field in shaft surface between adjacent air-gaps

. 5. The reluctance bridge and the Wheatstone bridge alogy of the cross torductor.



a) Orientation of reluctance-measuring cores

b) Electrical analogy

± σ Principal stresses
a_1, a_2, b_1, b_2 Air-gap reluctances for the two cores

A, B Reluctances of magnetic field in shaft surface between respective air-gaps
R Balance resistances

Fig. 6. Orientation of reluctance-measuring cores compared in electrical bridge and the electrical analogy with contact resistances affecting bridge balance.

When the shaft is subjected to torque, which results in the principal stresses $\pm\sigma$ as shown in the figure, the reluctances A and D, which lie in the direction of tension will be reduced, whereas the reluctances B and C, which lie in the direction of compression, will be increased. The result is that an unbalance magnetic flux will flow through the bridge arm $S_1 - S_2$ in proportion to the reluctance changes which, under suitable conditions, are proportional to the impressed torque.

Instead of crossing the two cores and using their windings as primary and secondary, they could be placed as in Fig. 6 a, where the inductances are balanced in a bridge. A represents the reluctance in the shaft surface between the poles a_1 and a_2, B the surface reluctance between b_1 and b_2. With the principal stresses indicated, the reluctance A is increased, i.e. the corresponding inductance is decreased, and the reluctance B is decreased, i.e. the corresponding inductance increased.

This arrangement has, however, one very big disadvantage compared with the cross torductor arrangement in Fig. 5, which is most clearly demonstrated by the electrical analogies, shown in Figs. 5b and 6b, for the two arrangements. The diagram in Fig. 5b can be compared with a full strain-gauge bridge on a rotating shaft in which case the "contact resistances" P_1, P_2, S_1 and S_2 at the slip rings do not disturb bridge balance, even if they naturally can impair the sensitivity. The diagram in Fig. 6b, on the other hand, can be compared with the case of the one half of a strain gauge bridge placed on a rotating shaft in which case the "contact resistances" a_1, a_2, b_1 and b_2 not only have an influence on the sensitivity but can completely upset the zero balance.

Linearity and hysteresis at different excitations

The cross torductor output voltage as a function of torque is shown in Fig. 7 for different values of magnetising ampere-turns, where increasing index corresponds to increasing ampere-turns. As will be seen, low magnetisation results in low sensitivity and, what is worse, a very marked hysteresis. The hysteresis decreases with increasing magnetisation and at the same time both sensitivity and linearity are improved up to a certain value for the magnetisation. With even higher magnetisation, lower sensitivity is obtained and the linearity between the output voltage and the torque is impaired.

The family of curves shown in Fig. 7 has been measured by means of a selective vacuum-tube voltmeter tuned to the fundamental. If the harmonics are included, the curves are not approximately linear even at that magnetisation giving the highest output. This magnetisation value is dependent upon and increases with the hardness of the shaft.

Modulation of the output due to inherent anisotropy

The cross torductor is designed for measuring the ma netic anisotropy of the surface under the measuri head, caused by the applied stress. The magnetic anis tropy is, however, not only caused by stress of extern or internal origin, but also by a possible orientation the crystals. As a large shaft is normally forged, it h a very complicated pattern of inherent anisotropy, part due to internal stresses and partly to crystallograph orientation. Normalising reduces this anisotropy co siderably, but the residual anisotropy is by no mea negligible. Whether this is mainly due to imperfect reli of stress or to residual orientation is of little importan for our purposes, as the result is in any case the sam To simplify the treatment we will therefore assume th the internal stresses play a dominating role and hereaft content ourselves with the term stress anisotropy whe referring to this phenomenon.

Due to the fact that the cross torductor measures th stress only in the surface under the measuring head, an lack of uniformity in the stress pattern around the ci cumference of the shaft will cause a correspondin change in the torductor output voltage when the sha is rotated. An example of how the output voltage (r.m. value) can vary around the circumference is shown i Fig. 8, which is measured for a laboratory test shaft wit a diameter of 200 mm (7 7/8"). The applied stress wa here only $\tau_{max} = 70$ kg/cm² (1,000 lbs/sq.in.).

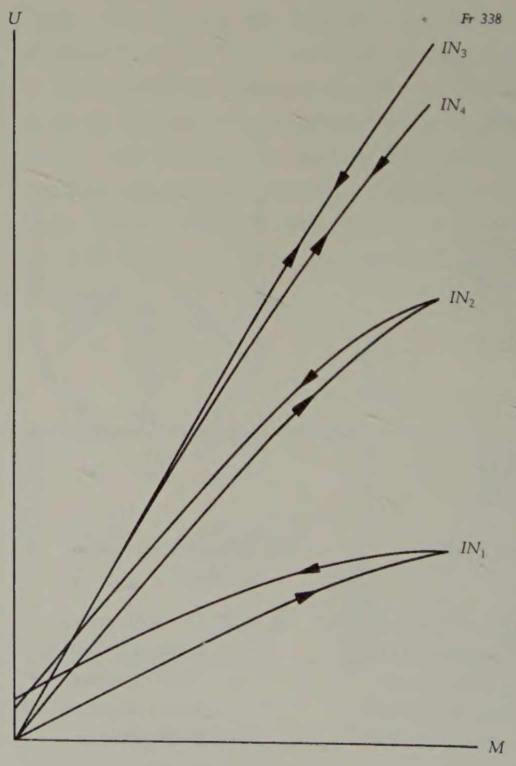
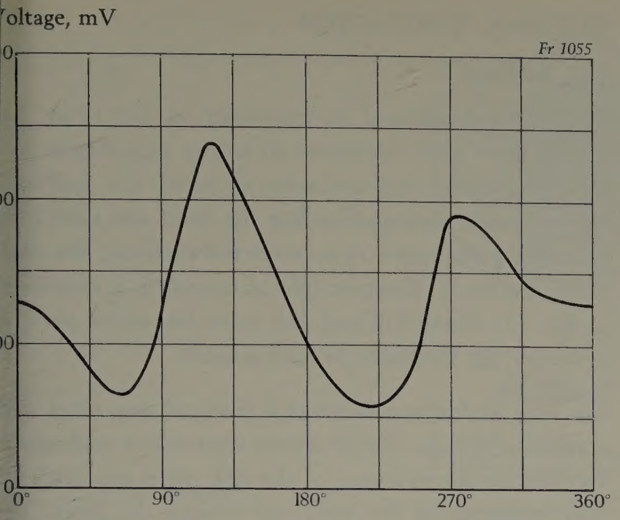


Fig. 7. Cross torductor output voltage U versus torque M f different values of magnetising ampere-turns IN.



-70 kg/cm² I_m=0.5 A δ=1 mm

ig. 8. Variation of cross torductor output voltage around ircumference of test shaft.

When the shaft rotates, these stress variations will cause a corresponding modulation of the output voltage. This modulation must obviously be filtered out from the ectified output before this can be used for regulation purposes. For this filtering a time constant of the same rder as the time for one revolution must be used. This onfines the use of the cross torductor to slow regulation n relation to the rotational frequency of the shaft as he necessary filter otherwise would introduce a disturbng time-lag in the control loop.

peed dependence

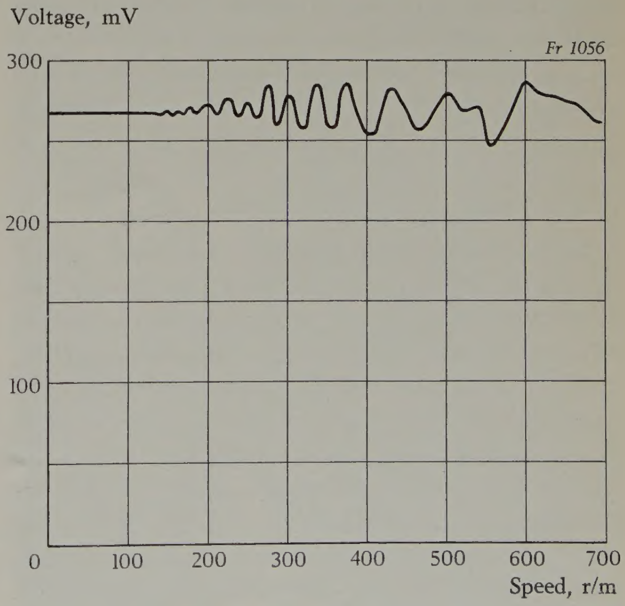
ny undesirable speed dependence in the torductor outut voltage may be caused by different effects.

ue to the rotation, eddy currents cause a transverse ield in the surface of the shaft underneath the two nergised pole-surfaces in much the same way as the rmature reaction is produced in electrical machines. f the torductor is asymmetric, this will cause a secondry voltage component that is proportional to the speed ut independent of the torque. If the measuring poles re symmetrically disposed, this effect is, however, elimiated.

more serious speed dependence is caused by residual nagnetisation of the shaft by the torductor. The effect s most easily explained by comparison with a magnetic ecorder; the shaft being the recording medium, the torductor primary core the recording head and the secondry core the play-back head. When the shaft is stationry, the remanence does not play any significant role nd the torductor output voltage is then solely caused y the time-derivative of the part of the primary flux which is linked with the secondary core as a result of he torque. When, on the other hand, the shaft rotates, a magnetic pattern is recorded on the shaft surface by the torductor primary core. With no torque, the field from this magnetic pattern has no effect on the torductor secondary, as this is balanced for this field in the same way as it is for the torductor primary field. With torque, however, the residual field is distorted in the same way as the primary field, and when this distorted, residual field passes the torductor secondary core an additional voltage is induced, which in principle is proportional to the torque, the degree of residual magnetisation and the speed.

The degree of residual magnetisation is on the other hand in itself speed dependent. At low speed the field patterns for neighbouring half-cycles overlap, so that the "recording" is continuously erased, eliminating the speed dependence of the output voltage. When the speed is higher and of such a value that the exciting frequency is an exact multiple of the rotational frequency, the magnetic pattern, recorded under one revolution, exactly coincides with the next one. This gives a "recorder voltage" which is in phase with the stationary torductor voltage, resulting in output voltage maxima at these synchronous speed values.

This can be seen from Fig. 9 in which the output voltage versus speed is shown for constant torque. The curve is measured at 50 c/s for the previously mentioned test shaft. At these maximum values in relation to speed the output also varies slowly up and down with time at constant rotational speed. This can be explained by a slow phase shift of the magnetic pattern relative to the internal stress pattern of Fig. 8. When a peak value of



τ=150 kg/cm² I_m=0.25 A δ=1 mm

Fig. 9. Cross torductor output voltage versus speed.

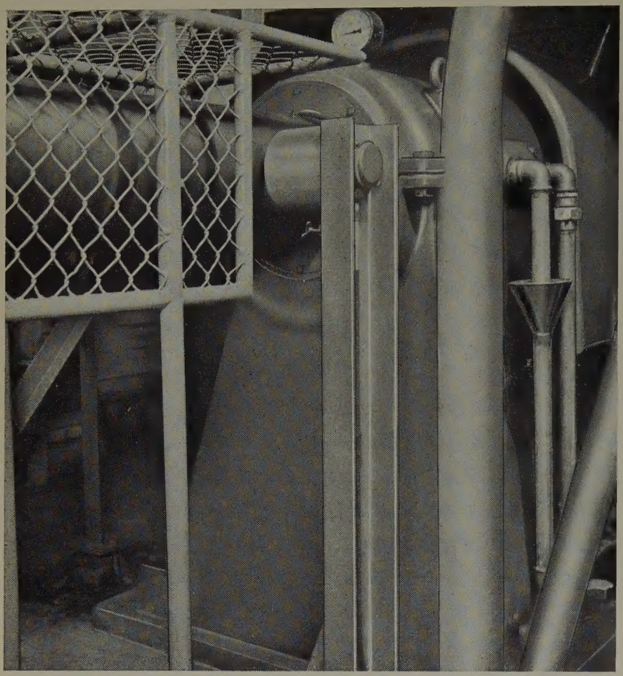


Fig. 10. A torductor in a paper-mill for regulating the feed to a water-turbine-driven grinder. (43958)

the internal stress pattern coincides with a point of maximum residual magnetisation, the output reaches a maximum value in relation to time, and when the stress maximum coincides with a point of zero magnetisation, the output has a minimum value in relation to time.

These cyclic variations in output voltage value in relation to both speed and time can naturally be very disturbing when using the cross torductor for regulation purposes. One possibility of getting rid of these effects is to supplement the cross torductor with a permanent magnet in such a way that the recorded pattern is continuously erased.

Practical applications of the cross torductor

When the internal-stress modulation and speed dependence of the output voltage are taken into consideration, it is quite obvious that difficulties may be encountered when applying the cross torductor to certain regulating problems. Because of this the cross torductor has never been released for general use. For the purpose for which it was originally developed, i.e. regulation of the wood feed to pulp grinders, it has proved very satisfactory, however, and quite a number have been delivered. As this case calls only for fairly slow regulation and the rotational speed is only about 200 r.p.m., the above-mentioned peculiarities of the cross torductor have apparently not interfered with the regulation in this case. The first installation of this type is shown in Fig. 10.

THE RING TORDUCTOR

The principle

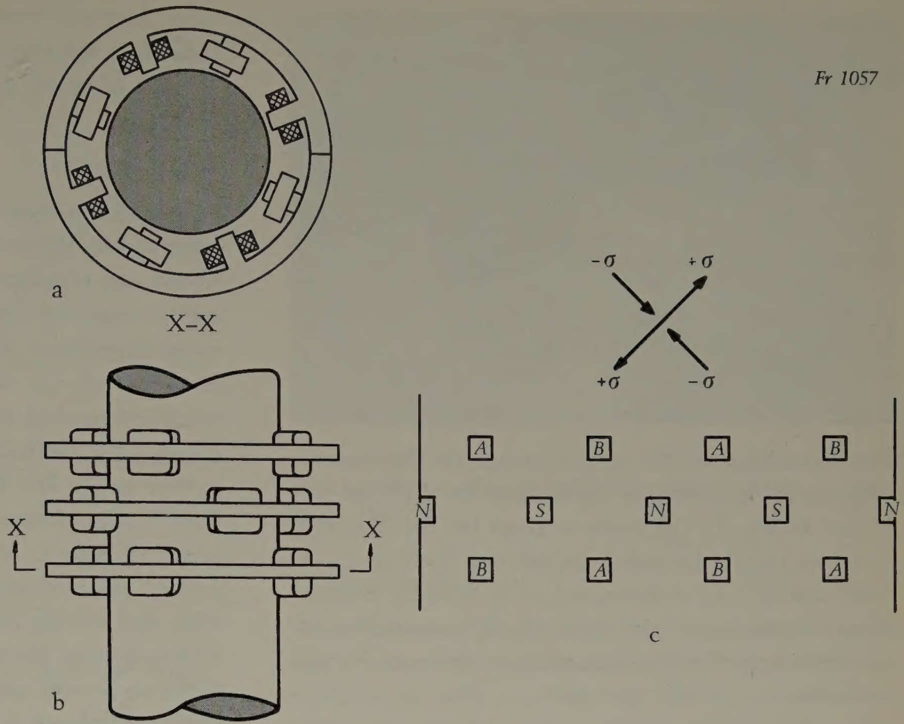
The above-mentioned shortcomings of the cross to ductor have been eliminated to a very high degree in new design, the ring torductor, in which the torduct has become a ring surrounding the shaft and somewha resembling the stator of an electrical machine, the shaf being the rotor. The principle of operation is illustrate in Fig. 11, where 11a and 11b show the active parts a 4-pole ring torductor around a shaft.

The ring torductor consists of 3 identical pole-rings wit a number of poles that is always chosen as a multiple o 4 to reduce the influence of the ring joints necessary fo easy mounting of the torductor around the shaft. Th poles are fitted with coils with alternately reverse winding directions. The middle ring is displaced half th pole-pitch relative to the outer rings and the distanc between the rings is approximately equivalent to hal the pole-pitch. The middle ring is normally used a primary and excited with 50 or 60 c/s. The two oute rings are used as secondaries and connected in series with mutually reversed winding directions, as indicate by the letters *A* and *B* in Fig. 11c, which shows th evolution of the shaft surface under the ring torducto and the projection of the poles. The primary poles ar marked *N* and *S* depicting a certain instant in the magnetising cycle.

If the shaft is unloaded and without internal stresses the magnetic fields between the different *N*- and *S*-pole will be symmetrical so that the zero equipotential line will be situated symmetrically under the secondary pole *A* and *B*. The secondary flux and hence the secondar voltage is thus zero at zero stress.

When torque is applied to the shaft, the principal stresse ± σ indicated in Fig. 11c are obtained. The permeabilit in the direction of tension, i.e. between the poles *B* an *S* and between *A* and *N*, is then increased, while th permeability in the direction of compression, i.e. between the poles *B* and *N* and between *A* and *S* is decreased. Thus all *A*-poles come magnetically nearer t the *N*-poles and all the *B*-poles magnetically nearer t the *S*-poles. The result is magnetically the same as if th secondary rings had been tangentially displaced in mutually opposite directions and opposite to the torsion o the shaft. The resulting fluxes through the poles cooperate in inducing an output voltage in the series coupled windings. The output is normally of the orde of 10 V and 1 mA, i.e. large enough for an instrumen without any amplification.

As the ring torductor measures almost uniformly aroun the shaft, the 45° stresses are virtually integrated aroun the circumference and the modulation of the outpu



±σ Principal stresses
N, S Primary poles
A, B Secondary poles

Fig. 11. The principle of the ring torductor, a and b showing physical arrangement and c evolution of shaft surface under the torductor poles.

voltage is thus reduced to a very small value. For the test shaft, for which the modulation of Fig. 8 was measured with the cross torductor, the modulation with the ring torductor is only ± 0.5 % at 240 kg/cm² (3,400 lbs/sq.in.) and the modulation frequency is 8 times the rotational frequency (8 poles) and thus much less detrimental from a regulation point of view. Because of this the ring torductor can be used for fast regulation problems outside the scope of the cross torductor.

The effective response time of the ring torductor is mainly determined by the exciting frequency and the desired degree of filtering of the output signal. For 50 to 60 c/s excitation it can be of the order of 10 to 30 ms, dependent on the circuitry chosen.

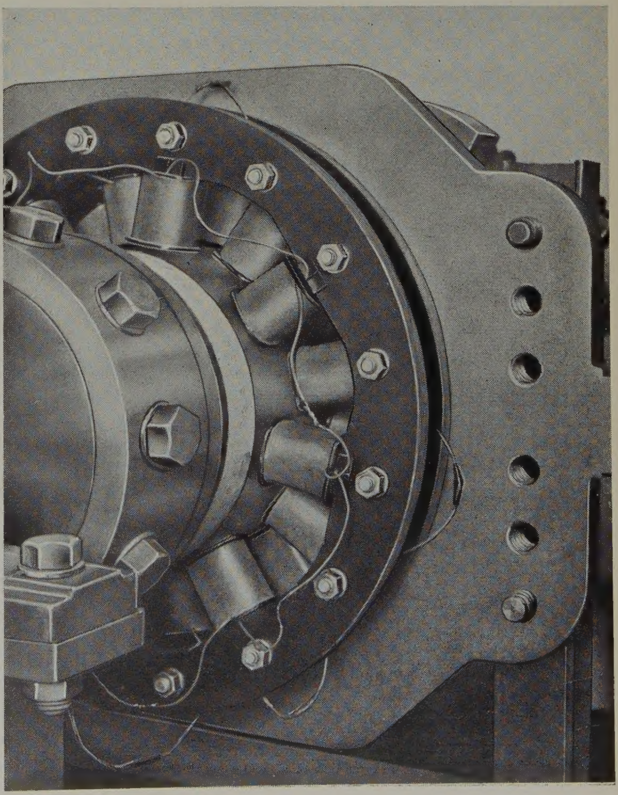
As both the zero voltage and the sensitivity now are a result of an integration around the circumference, the ring torductor can be statically calibrated with good accuracy.

The calibration has to be performed with the torductor mounted around the shaft as the sensitivity is dependent on its composition and heat treatment. This is, however, a drawback which the ring torductor in principle shares with all other torque-meters. With the exception of the torductor they are all based on measuring strain or torsion and therefore depending on the shear modulus. As this can vary appreciably with composition and heat treatment, a calibration together with the shaft is always advisable for greatest accuracy.

Fig. 12 shows the first laboratory model of a ring torductor mounted around the test shaft. The primary and one of the secondary pole-rings (nearest) can be seen in the picture.

The ring torductor is made in two identical halves. Fig. 13 shows such a ring torductor half, complete with shielding end-plates.

Fig. 12. Laboratory model of ring torductor, mounted around test shaft. (50644)



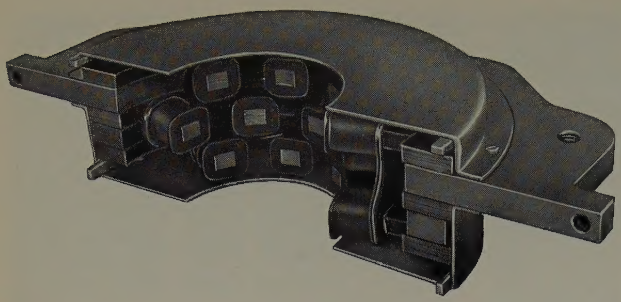


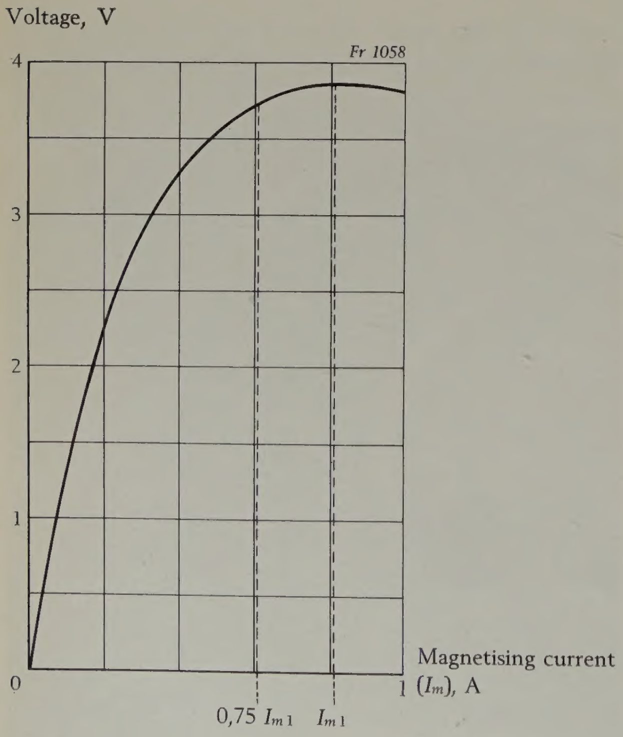
Fig. 13. *A ring torductor half.* (51363)

Magnetisation dependence

The dependence of the output voltage on the magnetising current is essentially the same as for the cross torductor. In Fig. 14 the curve is given for the first ring torductor sample (8 poles) on the test shaft at $\tau_{max}=$ $=300$ kg/cm² (4,250 lbs/sq.in.). If a working point is chosen at the top of the curve (I_{m1}), a constant voltage transformer for the excitation can obviously be dispensed with.

Linearity and hysteresis

In Fig. 15 the output voltage as a function of stress is shown for the same test set up. The magnetising current I_{m1} giving maximum output voltage obviously gives the best linearity and negligible hysteresis. At a magnetising current of 75 % of I_{m1} the linearity is, however, nearly as good and the hysteresis also very small. Even if this value does not here show any advantages over I_{m1} w shall soon see that it can be desirable from the poin of view of speed dependence.



$\tau=300$ kg/cm²

Fig. 14. Ring torductor output voltage versus magnetising current.

Speed dependence

The output voltage as a function of rotational speed i given in Fig. 16 for the same test set up as earlier mentioned and at a stress of 200 kg/cm² (2,840 lbs/sq.in.) and a magnetising frequency of 50 c/s. For I_{m1} the speed dependence is not negligible even at low speeds. At 75 % of I_{m1} the speed dependence is obviously much less marked and up to 500 r.p.m. (200 mm shaft, 8 poles) the variation of the output voltage with speed is very small. For both values of magnetising current there is a maximum at 750 r.p.m., i.e. the synchronous speed (8 poles). At this speed the residual magnetic pattern recorded under one half-cycle exactly coincides with that for the following half-cycles. As in the cross torductor case, this pattern induces a "recorder voltage" in the secondary, which is in phase with the stationary torductor voltage at the synchronous speed, resulting in a marked maximum in the output voltage. As the speed dependence is a result of the residual magnetisation, it is quite natural that it increases with increasing excitation.

If the speed for a certain application is so high that the speed dependence becomes disturbing, this can always be cured by choosing a higher excitation frequency which increases the speed-independent speed range proportionately. This applies naturally both to the cross torductor and the ring torductor.

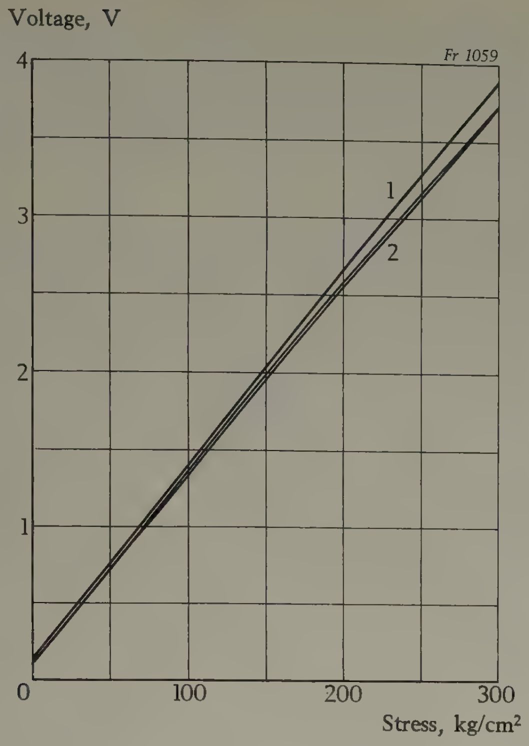
Optimum magnetisation depending on speed range

The optimum magnetisation is apparently dependent upon the required speed range. For very low speeds it may be preferable to use I_{m1} in order to get the best possible linearity and freedom from hysteresis, at the same time gaining the advantage that a constant voltage transformer for the excitation then can be dispensed with.

When a constant output over a big speed range is essential, a compromise of $0.75 \times I_{m1}$ may be necessary if the required speed range is not achieved by raising the excitation frequency.

Dependence on frequence and temperature

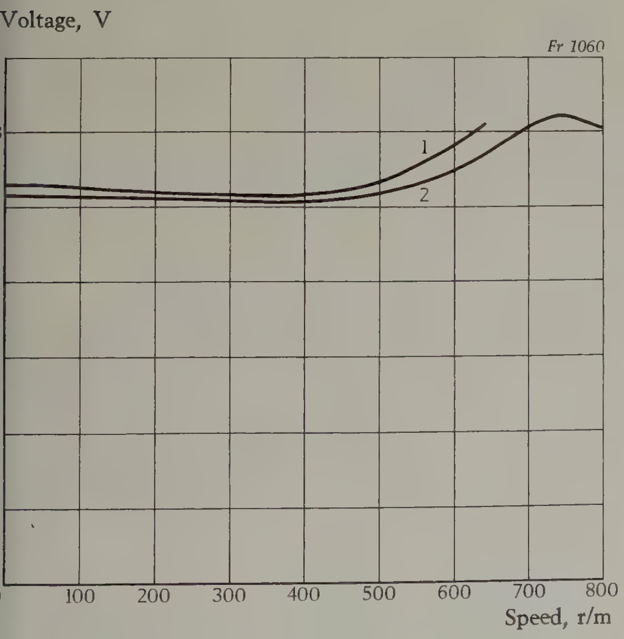
Some of the factors affecting the output voltage have a positive frequency-dependence and some a negative one. The net result can therefore vary, depending upon excitation and other conditions. As the secondary normally is tuned to the fundamental, a positive or negative frequency-dependence can be corrected by suitable choice of the tuning capacitance.



1 Magnetising current I_{m1}
2 Magnetising current 0.75 I_{m1}

Fig. 15. Ring torductor output voltage versus stress.

The temperature-dependence is likewise composed of many factors partly opposing each other and the resulting temperature-dependence can be eliminated by choosing the right resistance material in the output circuit.



$=200$ kg/cm²
Magnetising current I_{m1}
Magnetising current 0.75 I_{m1}

ig. 16. Ring torductor output voltage versus speed.

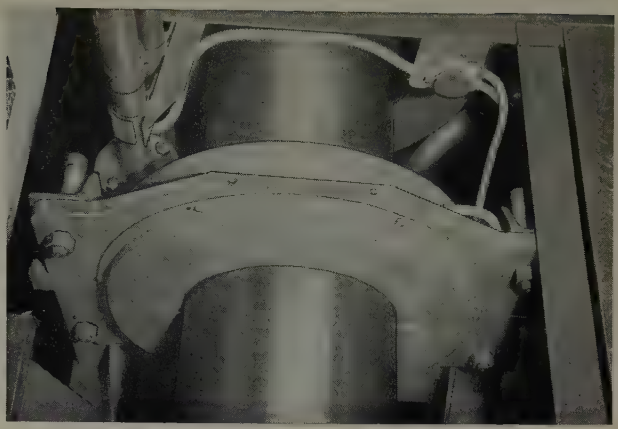


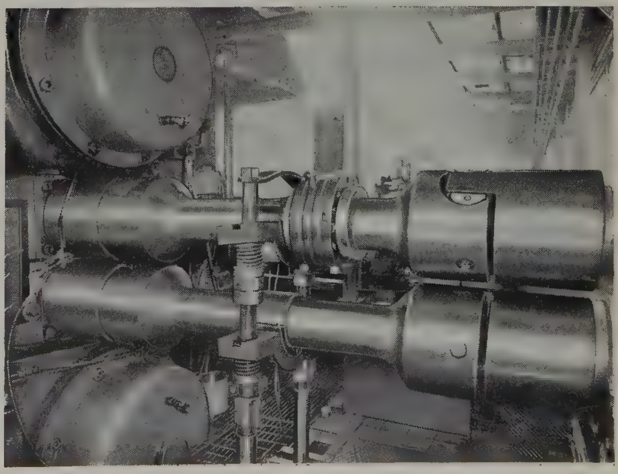
Fig. 17. Ring torductor installed around a ship's propeller shaft. (53271)

Practical applications

As indicated in the introduction there should be many uses for a robust torque-gauge in industry. As the ring torductor is quite new and only recently left the laboratory stage, it has so far only been possible to apply it to some special problems.

Two 16-pole ring torductors have thus been installed on a Swedish twin-screw cargo ship, m/s Montevideo, during her maiden voyage to South America. The measured torque values checked well with the values calculated in the normal but cumbersome way from fuel consumption, exhaust temperature, cooling water temperature etc., whereby the calculation is based upon the efficiencies obtained with a water brake during the engine trials. Through a routine comparison of such measurements, a possible deterioration of the engine efficiency could be detected at an early stage, eliminating unnecessary fuel consumption. A decrease in efficiency could

Fig. 18. Ring torductor mounted riding on rolling mill spindle. The supporting structure in the centre of the photograph is part of the spindle assembly and has nothing to do with the ring torductor. (53370)



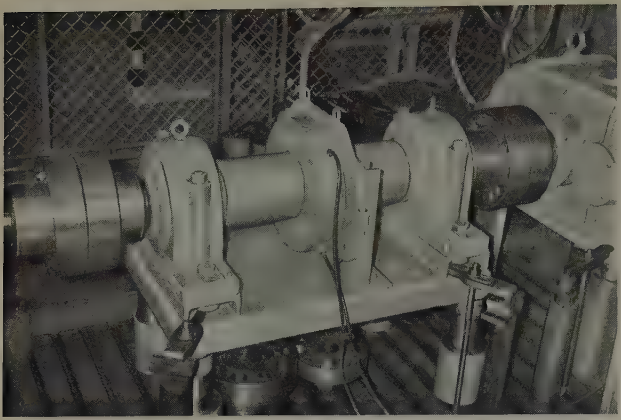


Fig. 19. Combination of ring torductor and special measuring shaft applied to testing of gearboxes. (53481)

otherwise only be judged from a decrease in speed, but speed is rather a poor indicator of the motor efficiency as the speed is also influenced by many other factors such as high winds, waves and currents, bottom fouling etc. Moreover, a ring torductor installation gives the engine-room staff a continuous indication of the instantaneous power yielded. By adding a recorder, a very useful objective "engine log" can be obtained. The torductor installation could with great advantage be complemented with a pressductor [1, 2] installation in the propeller-shaft thrust-bearing, as this gives the possibility to check independently the efficiencies of the engine and the hull plus propeller. The experimental installation on m/s Montevideo, which included a pressductor installation, produced such promising results that the whole outfit has been permanently installed on a later sister ship, m/s Santos. The ring torductor installation is shown in Fig. 17.

Automatic control of variable-pitch propellers to keep the torque and thus the load on the diesel engine constant is another problem for which the ring torductor has been considered and some preliminary experiments have been made.

As mentioned earlier, the rolling mill people are interested in measuring the torque in the spindles driving the rolls. In a two-high or four-high mill the two work-rolls are usually driven from a pinion stand with the ratio 1:1. If the two rolls have not exactly the same diameter, there will obviously be a difference in peripheral speed. This results in a shearing in the rolled material, giving it a tendency to curl. The shear stress is reflected back to the drive as differing torques in the two driving spindles. If each spindle is equipped with a ring torductor, this gives the operator a good indication of the division of the torque between the two rolls and hence of the degree of matching between the roll diameters.

Apart from the very rigorous environment there is in this case the special problem that the spindles are not supported by any bearings but mounted floating in two claw-couplings, thus changing position with the roll gap. The ring torductor must therefore be mounted riding on the spindle, and kept from rotating by a link arrangement. The first installation of this type is illustrated in Fig. 18.

A ring torductor installation on the spindles is naturally also of great value for measuring the transient rolling torque, especially when the inertia of the driving equipment is increased by a flywheel, in which case the motor current is a poor indication of the instantaneous torque.

A calibrated combination of a special shaft and a ring torductor can naturally be useful as a general torque-meter for test rooms and laboratories. Fig. 19 shows such an arrangement used for the testing of gearboxes.

As mentioned earlier, the cross torductor has been used exclusively for controlling pulp grinders, but even this field will probably be taken over by the ring torductor because of its higher and more consistent output and because it is less speed dependent, making the control system simpler and easier to adjust.

Another application, for which the ring torductor has so far only been proposed, is for indication and, possibly, control of drilling torque in the petroleum industry. Here its robustness and freedom from electronic amplifiers should be very desirable features, especially as oil-drilling often has to be performed under the extremes of environmental conditions.

CONCLUSIONS

The ring torductor is a robust torque-meter for heavy industry with the following salient features:

Stationary mounting around existing shaft for which no modifications or attachments whatsoever are required.

Short length, making installation possible even under cramped conditions.

Non-contacting, eliminating the effect of dirt and moisture, which could be especially detrimental to slip rings.

High output power, eliminating the problem of interference from neighbouring cables and making indication and recording possible without any amplification.

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AN INTERESTING MINE-HOIST DELIVERY TO SCOTLAND

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U.D.C. 622.67
Asea Reg. 632

number of multi-rope, friction-drive mine hoists have ecently been delivered by Asea to the National Coal oard of Great Britain. This article describes the mine oist installed at the Seafield Colliery, East Fife, Scot- nd, which is probably the first pushbutton-operated riction hoist in the world working with induction-motor rive and dynamic braking.

uring 1958 four Asea multi-rope, friction-drive hoists ere commissioned at various collieries belonging to the ational Coal Board of Great Britain. These mine hoists, hich are driven via spring-mounted precision gears, are ll set up at the top of the headframe. One of the mine oists, which is installed at the Cynheidre Colliery in armarthen, Wales, is driven by a d.c. motor, regulated ccording to the Ward-Leonard system. The other three nits, which have all been delivered to Scotland, two at e Kames Colliery, Ayrshire, and one at the Seafield olliery, Fife (Fig. 1), are driven by three-phase induc- on motors. The latter three units are of particular inter- st as, due to the working conditions, induction-motor rive could only be adopted when combining it with .c. braking. The mine hoist (Figs. 2 and 3) at the eafield Colliery is probably the first pushbutton-oper- ted friction-drive hoist in the world operating with this ystem.

considerable number of automatic and pushbutton- perated ore and service mine hoists have been delivered y Asea over the last few years with three-phase induc- on motors. The speed is then regulated by the service rake in combination with re-connection in steps of the econdary resistor of the motor. In the case of a skip oist which raises a fairly constant load, such a regu- ting system can be adopted also for hoists having large otor outputs, provided that the load is sufficient to etard the hoist within the stipulated time when the otor torque is decreased due to the connection of the econdary resistor. The service brake need only inter- ene after the hoist has been slowed down to a low eed so as to make any corrections should the speed f the hoist deviate slightly from the desired creep speed.

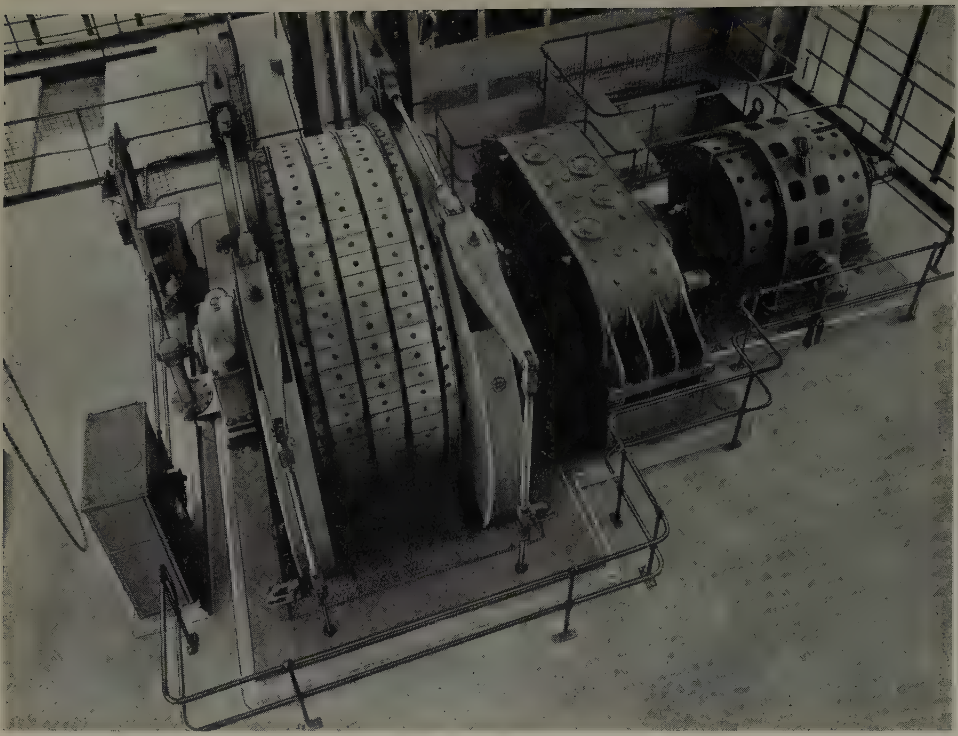
peed regulation on the above lines with the service rake has proved to be very satisfactory also for smaller ervice hoists working under extremely variable load onditions despite the fact that the service brake must equently intervene also during the retardation. In the ase of higher speeds and larger loads, however, the nergy which has to be absorbed by the brakes, especially during the retardation of a descending load, leads to excessive heating. Should it be desired to employ induction-motor drive also for this type of service, retardation with the service brake must be replaced by electrical braking.

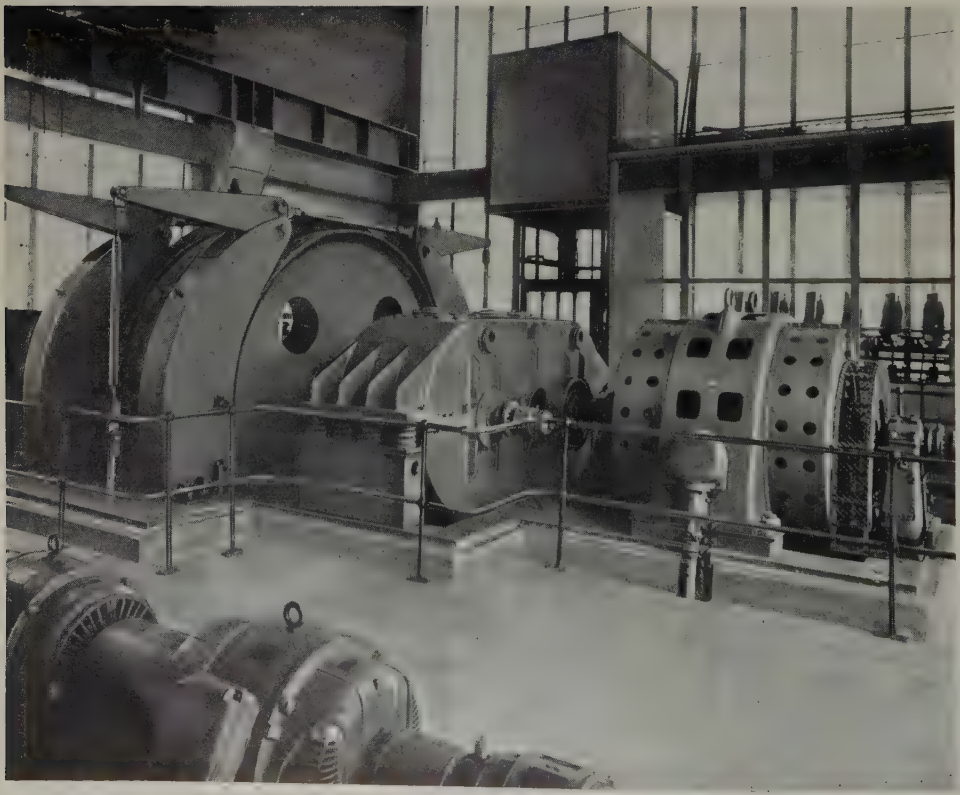
If d.c. braking is adopted, the hoist motor is disconnected from the network and is connected instead to a small d.c. generator. When the hoist motor is energised with d.c., it operates as an a.c. generator and brakes the hoist. The energy resulting from this braking is converted into heat in the secondary resistor of the motor.

As will be described in this paper, by designing a suitable regulating system for d.c. braking and combining this with the previously mentioned regulation with the service brake, Asea has succeeded in developing a system with the following features:

1. Continuous speed regulation right down to creep speed for all loads.

Fig. 1. The headframe for shaft No. 2 of the Seafield Colliery, near Kirkcaldy, East Fife, Scotland. This colliery is one of the major new sinkings being developed by the National Coal Board, and it is intended to exploit the extensive coalfield lying beneath the bed of the Firth of Forth. (53779)





Figs. 2 and 3. The four-rop
friction hoist is driven b
an induction motor havin
a rating of 900 h.p. via
spring-mounted precision
gear unit.

In Fig. 2 the retardatio
potentiometers and the
hoist-regulator, which are
driven from the hoist sha
can be seen. These device
form part of the auxiliar
control equipment of th
hoist.

The motor-generator set fo
the d.c. braking, rated at 3
h.p., is visible in the fore
ground in Fig. 3.
(53781, 53780)

Constant retardation and creep speed irrespective of the load.

Additional safety due to two retardation systems operating independently of one another.

his system is extremely suitable for both manual and ushbutton service, thanks to the above features. A brief resentation of the installation at Seafield Colliery, where is system was first applied, will be given in the following text, reference also being made to the illustrations.

IAIN DATA

two-deck cage (Fig. 4) balanced by a counterweight used for combined men and material hoisting between ne surface and two underground levels at 170 fathoms 300 metres) and 300 fathoms (560 metres). The large age, while normally carrying one mine car per deck, as sufficient space for carrying extra wide material and an take 50 men per deck.

he mine cars are moved in and out by means of automatic loading arrangements and the decks are changed y means of pushbuttons at the levels. Tilting, pneumatically operated platforms are provided at each level facilitate the loading and unloading of the mine cars the cage. The cage runs on four rope guides. Fixed uides, however, are arranged at the top and bottom f the shaft (see Figs. 5 and 6). At the intermediate vel, where it is impossible to use fixed guides, a special etaining device has been fitted, this locking the cage to position while it is being loaded. Electrical interlocking is arranged so that the hoist can only be operated the creep speed when the retaining device or platorms have been extended. Also at each level before latforms can be lowered or gates opened, the cage must e proved at the level via switches provided.

et load	7.5 tons
Veight of two mine cars	3.0 tons
Veight of cage	12.5 tons
Veight of counterweight	19.25 tons
ulley diameter	10 feet (3.05 m)
opes (of locked-coil type):	
Number	4
Diameter	1 1/8 in. (29 mm)
epth of shaft	1,850 feet (560 m)
oist-motor data	900 h.p., 750 r/m, 6.6 kV
oisting speed	30 ft/sec. (9.1 m/sec.)

he pulley is provided with elmwood lagging having rned grooves for the four ropes.

HE PRINCIPLE AND DESIGN OF THE D.C. RAKING SYSTEM

he basic circuit is shown in Fig. 7. When the hoist is eing braked, the induction motor is disconnected from the network via the reversing contactor 1, and two of its phases are connected up instead to the d.c. generator 5 as a result of the braking contactor 2 picking up. The field winding of the d.c. generator is connected to the metadyne amplifier 6, the field winding of which is fed, in its turn, with the difference voltage between the voltages from a tachometer generator 7 driven by the hoist motor and a reference potentiometer 8. The voltage of the tachometer generator represents the actual speed of the hoist and the voltage across terminals *a* and *b* of the potentiometer the desired speed. If the tachometer-generator voltage is higher than that of the reference potentiometer, the metadyne will supply field current to the d.c. generator which, in its turn, feeds the stator winding of the induction motor. The hoist is then braked until the voltages of the tachometer generator and potentiometer are roughly the same. Due to this arrangement, the d.c. excitation of the induction motor is automatically regulated so that the motor produces the braking torque required for the speed to correspond to the desired value given by the reference potentiometer.

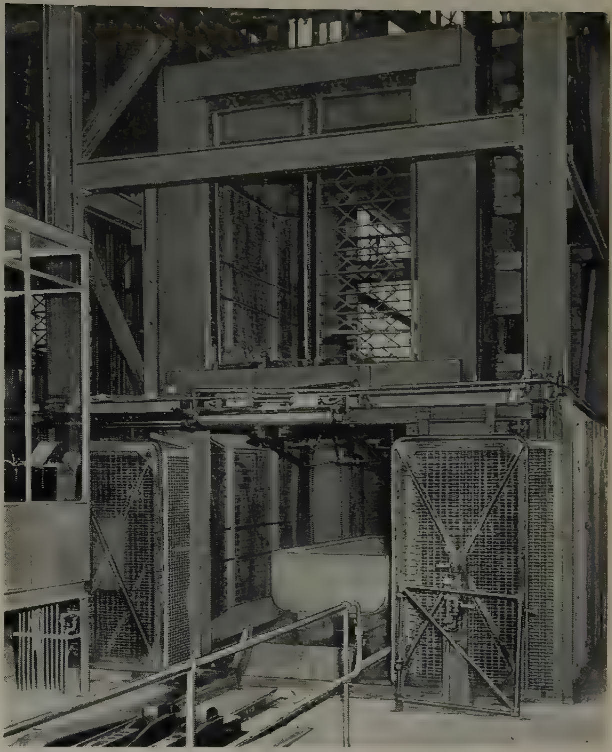


Fig. 4. A two-deck cage balanced with a counterweight is used for conveying both men and material. Pneumatically operated mine-car loading devices and withdrawable platforms are provided at each level. The decks are changed with the aid of pushbuttons. To the left in the photograph the cabin containing the control desk for the hoist and the levers used for operating the loading arrangement for the mine cars at ground level can be seen. (53786)

The braking torque developed by the induction motor at a certain excitation current will be dependent on both

Figs. 5 and 6. The cage and counterweight run on rope guides. Fig. 5 shows how these guides are anchored in the headframe. Fixed guides are arranged, however, at the end positions of the shaft, and the system adopted is depicted in Fig. 6. (53785, 53789)

the speed of the motor and the size of the secondary resistance connected to the slip-rings.

The braking torque M_b has been plotted in Fig. 8 as a function of the speed n divided by the secondary resistance R_2 for a few values of the excitation current $I_1 - I_5$. The secondary resistor is short-circuited in steps during the retardation at certain speeds via voltage relays on the tachometer generator. The quotient n/R_2 is thus kept within the limits a and b throughout the retardation. When braking starts from full speed, the secondary resistor is set to such a value that n/R_2 at full speed becomes b. Assuming that a braking torque M_{b1} is required, the excitation current in the first instance will become I_4. As the speed drops, that is to say, the quotient n/R_2 decreases, the excitation current required to produce the braking torque M_{b1} will first decrease and reach a minimum value slightly less than I_3. It will then have to increase again when the speed drops still further. As soon as the speed has dropped to a value where $n/R_2 = a$, part of the rotor resistor is short-circuited so that the quotient n/R_2 once again becomes b. By correlating the short-circuiting of the secondary resistor with the speed in this way, the motor will be able to develop the required braking torque throughout the retardation without the need for any excessive excitation currents.

SPEED REGULATION WITH THE MECHANICAL BRAKES

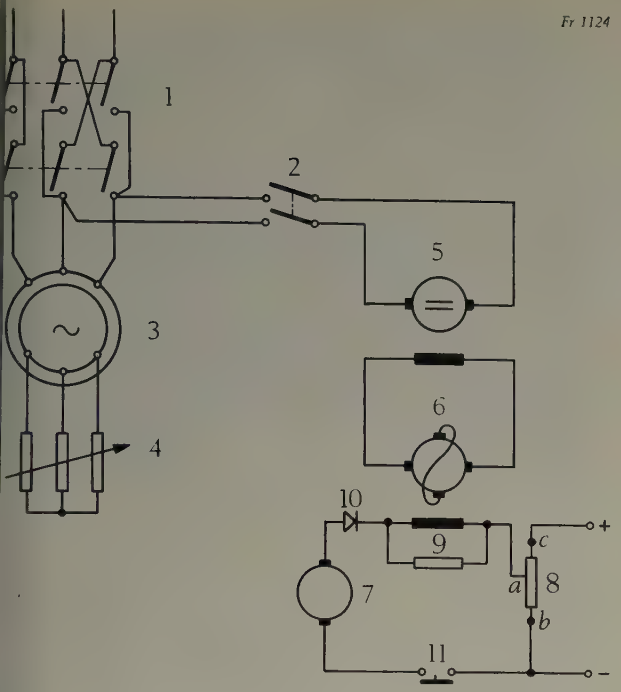
The service brake is utilised for regulating the creep speed for an ascending load. The brakes are pneumatically operated, and the pressure in the service brake is regulated via a sensitive electro-pneumatic regulator. This senses the difference voltage between the voltage from yet another tachometer generator, driven by th hoist, and a separate reference potentiometer in basicall the same way as described for the electrical brakin system. If the tachometer generator voltage is highe than that of the reference potentiometer, that is to sa the speed of the hoist is higher than the desired spee the electro-pneumatic regulator will increase the pres sure to the service brake, which then reduces the spee to the desired value.

OPERATION OF THE HOIST

The Seafield installation is designed for both manual an pushbutton operation. The latter operating system used for all transport of material, whereas service hois ing is controlled by a winding engineman owing to th present British Mine Safety Regulations in force. Th change-over from manual to pushbutton operation made with a change-over switch on the control des The two operating systems will be described in greate detail in the following.

Manual operation

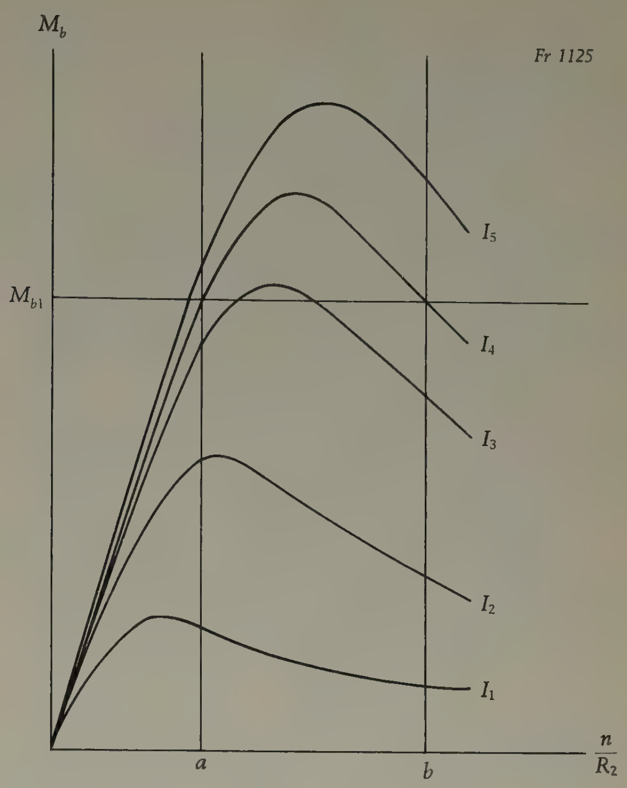
The mine hoist is remotely operated from the contr desk set up on the ground level (Fig. 10), the movemen being controlled with the aid of a controller lever and braking lever. The controller lever moves in a slot shape in the way shown in Fig. 11. It is moved out of the 0-p sition by making a short movement to the left or righ depending on the winding direction desired. The d. braking contactor, which connects up the hoist mot



Reversing contactor
Dynamic-braking contactor
Hoist motor
Contactor-operated resistor
Dynamic-braking generator
Metadyne amplifier
7 Tachometer generator
8 Potentiometer for reference voltage
9 Current-limiting device
10 Rectifier
11 Auxiliary contact from dynamic-braking contactor

g. 7. The hoist is retarded by means of d.c. braking, which nplies that the hoist motor 3 is disconnected from the net- ork and connected instead to a small d.c. generator 5. The aking current is regulated with a metadyne amplifier 6, hich is fed with the difference voltage between the volt- ges from a tachometer generator 7 and a reference potentio- eter 8. The braking current is consequently regulated auto- atically in such a way that the winding speed corresponds the desired speed determined by the position of the refe- nce potentiometer.

the d.c. generator, is energised when the lever is oved to either side position. As soon as the controller ver is moved out into either of the parallel slots, the c. braking contactor is disconnected and the hoist otor is connected to the network via one of the re- rsing contactors. The controller has six power positions each direction. When the lever is in the first position, e entire secondary resistor is connected up to the rotor rcuit of the hoist motor. In positions 2 to 5 the first ur contactors are successively closed. In the 6th po- ion the secondary resistor is short-circuited by the maining secondary contactors via current-limiting re- ys. If the controller is moved suddenly, the current- niting relays determine also the rate of connection for e first four contactors in order to prevent the hoist otor from being subjected to large current surges.



n	Speed of hoist motor
R_2	Total secondary resistance of hoist motor
M_b	Braking torque of hoist motor
$I_1 - I_5$	D.C. excitation of hoist motor

Fig. 8. The braking torque M_b developed by an induction motor when it is excited with a certain direct current I_1, I_2, I_3, etc., is dependent both on the motor speed n and the size of the secondary resistance R_2 connected to the slip-rings.

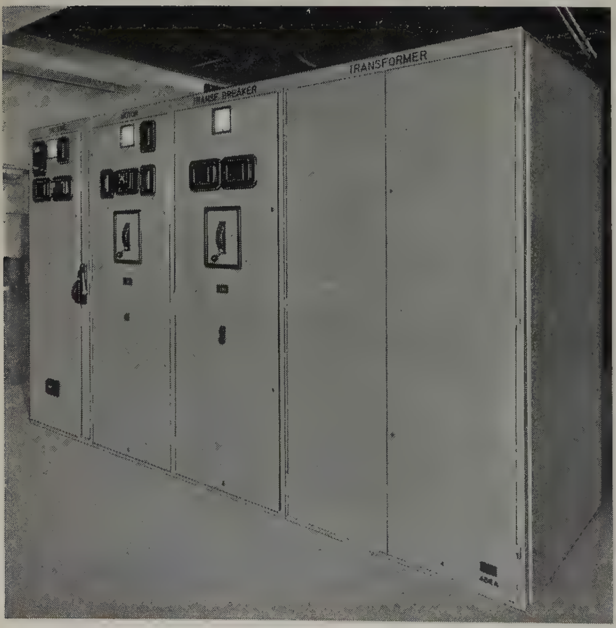
The braking lever operates the two reference potentiometers mentioned previously for the electrical and mechanical braking. As has already been described, the two regulating systems are designed so that a certain reference voltage corresponds to a certain speed. This means that a certain position on the braking lever corresponds to a determined speed which cannot be exceeded. When the controller is in a power position, the regulating system for the service brake sees to it that the speed of the conveyance in the shaft corresponds to the value determined by the position of the braking lever. If, on the other hand, the controller stands in the position for d.c. braking, both regulating systems are connected up. In order to prevent the service brake from taking part unnecessarily in the speed regulation, its regulating system is set for all the positions on the braking lever to a slightly higher speed than that of the electrical braking. Since both regulating systems are connected up for d.c. braking, an added margin of safety is achieved, as the service brake intervenes automatically and takes over the speed regulation should any fault occur on the d.c. braking system. In other words, the service brake system will "shadow" the d.c. braking system over the entire speed range.

The hoist is operated in the following manner:

When either the braking lever or the controller lever stands in the 0-position, the brakes are fully applied and both the reversing and the braking contactors are disconnected. If the hoist is to be started up, the controller lever is moved out into one of the power positions. When the braking lever is then taken out of the 0-position, the reversing contactor for the direction to be taken by the conveyance picks up. The hoist then starts and accelerates up to a speed determined by the position of the braking lever. For further acceleration up to full speed, the controller lever is moved to position 6 at the same time as the braking lever is set to the position for full speed. The contactor-operated secondary resistor is then successively short-circuited via the current-limiting relays.

When retardation is to be commenced, to begin with, the controller lever is moved to the position for d.c. braking for the winding direction in question. The hoist motor is then disconnected from the network and connected instead to the d.c. generator. The regulating system for the d.c. braking continues to regulate at full speed right up to the instant when the engineman starts to move back the braking lever. The speed of the conveyance in the shaft will then follow the movement of the braking lever down to the creep speed. The hoist motor i finally stopped as a result of either the braking leve or controller lever being set to the 0-position.

Fig. 9. The high-voltage switchgear is housed in a group of metal-clad cubicles and includes an isolating switch, motor-operated oil-minimum circuit-breakers for the hoist motor and the auxiliary transformer. This latter unit is placed in the right-hand cubicle shown in the photograph. (53782)



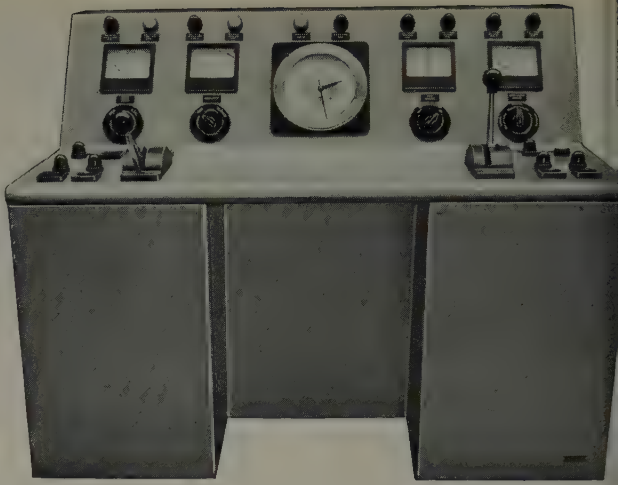


Fig. 10. During manual operation the mine hoist is remotel operated from the control desk set up on the ground leve The right-hand lever is the controller lever and the left-han one the braking lever. The latter actuates the two referenc potentiometers for the service brake and the d.c. brakin system, which are electrically interconnected in such a wa that each position on the brake lever corresponds to a certai fixed speed, irrespective of the size of the load. (46597)

In the case of an ascending load, the controller leve must be moved to a power position after the creep spee has been attained to enable the motor to yield a sufficient amount of torque to move the cage up to th appropriate station. The creep speed is then regulate by the mechanical brakes and is still determined by th position of the braking lever.

Pushbutton operation

Two pushbuttons are provided at each level, by means o which it is possible to dispatch the cage to either of th other two levels. In addition, two pushbuttons "Slow up and "Slow down" are provided at each level for use i conjunction with deck changing and levelling of the cage

When the hoist is being operated by pushbuttons, th reference potentiometers controlled by the braking leve are replaced by two other reference potentiometers which are driven directly from the hoist shaft during th retardation period. In this way, the reference voltage and consequently also the speed of the hoist, will b directly dependent on the position of the cage in th shaft. These reference potentiometers are wound in suc a way that a constant retardation is obtained.

When a starting signal is given, the motor is connected o the network via the reversing contactor for the actual irection to be taken by the cage. The contactor-operted secondary resistor is short-circuited in steps at a ate set by the current-limiting relays. The reference oltage for the service brake is set during the accelertion to full speed, thus causing the brakes to be comletely disengaged. When the cage passes the point in he shaft where retardation is to commence, a contact n the hoist regulator (see Fig. 2) gives a signal for etardation. The hoist motor is then disconnected from he network and connected instead to the d.c. generator. At the same time, the two reference potentiometers are onnected to the hoist shaft via an electro-magnetic oupling. As the cage approaches its destination, the eference voltage drops and the hoist is slowed down o the creep speed by d.c. braking at a constant rate of etardation.

As is the case with manual operation, the regulating ystem of the service brake is set to a slightly higher peed than that for d.c. braking. Consequently, the serice brake will not normally intervene during the retarlation but will only supervise the d.c. braking.

When large loads are being hoisted, d.c. braking is often ot required. During the retardation the motor then renains connected to the network and supplies any aditional torque required to prevent the load from retardng the hoist too rapidly. The service brake supervises etardation by means of the reference potentiometer riven by the hoist and intervenes to the extent required o obtain the desired retardation.

A current relay, which senses the motor current during he period of full speed, decides whether the motor can emain connected to the network during the retardation. During the period of full speed a power-direction relay lso checks whether the hoist is driving, or being driven y, the load. This relay decides in advance whether the oist motor is to be re-connected to the network after he creep speed has been attained in order to drive the age to its destination or whether it is to remain conected to the d.c. generator also during creeping, the reep speed being regulated in this case by means of the .c. braking. When the cage has reached the desired evel, the final stopping signal is given by means of mehanical limit switches in the end positions of the shaft. At the intermediate level, on the other hand, the cage s stopped by a photo-electric cell.

When changing the decks of the cage, the hoist is operted, as already mentioned, from pushbuttons placed by he shaft. The motor is then connected up to the network ia the reversing contactors. At the same time, a sufciently large portion of the secondary resistor is short-circuited to enable the motor to raise the largest load liable to occur. The speed is regulated by the service brake, the reference voltage of which is automatically set to the creep speed for this operation.

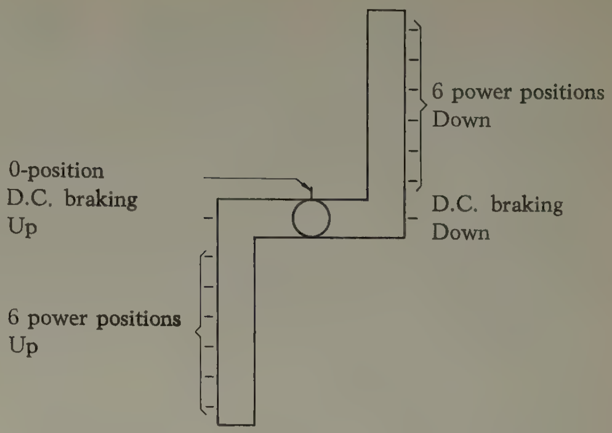


Fig. 11. The slot for the controller lever. (Fr 1126)

The automatic retardation is allowed to function at the end positions of the shaft also during manual operation of the mine hoist so as to afford the greatest possible safety. This is achieved in such a way that the reference voltage from the manually operated potentiometers is compared with the reference voltage from the potentiometers driven by the hoist. The electrical circuit is designed so that the speed will always follow the potentiometer having the lowest voltage. This means that the engineman may retard the hoist more rapidly than the prescribed value. If he does not manage to retard it sufficiently quickly, however, the potentiometers driven by the hoist will take over the retardation of the hoist.

CONCLUSION

The experience gained from the mine-hoist installation at the Seafield Colliery indicates that service with a three-phase induction motor having combined d.c. and mechanical braking can be successfully adopted even for pushbutton-operated service hoists having relatively high winding speeds and large motor outputs. The range of application for induction-motor service can thus be extended to cover severe operating conditions, which could otherwise only be met by employing d.c. motors with Ward-Leonard control.

ACKNOWLEDGEMENT

Acknowledgement is made to the National Coal Board for permission to publish this paper and also for the facilities provided to photograph the mine-hoist installation.

THE RAPIDE BLANC POWER-STATION, CANADA

Rudolf Garmo, Power Engineering Division, Västerås

U.D.C. 621.311.21(7
621.313.322-
Asea Reg. 4421, 721

In conjunction with the enlargement of various power-stations along the river St. Maurice, Canada, Asea have supplied certain items of equipment including a generator for the Rapide Blanc Power-station. The generator is described briefly in this article.

The Shawinigan Engineering Company is a private power-supply company which exploits the hydro-electric resources of the river St. Maurice in the province of Quebec, Canada (see Fig. 2). In 1953 this company was obliged to install an additional generator in each of the power-stations at La Tuque, Trenche and Rapide Blanc. At the same time, it was found necessary to install an extra synchronous condenser with a rating 40 MVA at the transformer substation of Limoil situated at the end of the 66 kV transmission line Quebec, in order to increase the total reactive pow to 70 MVA. By relieving the transmission line in th manner it would be possible also to improve the regul tion of the voltage.

Among the machines required for these extension Asea have supplied the generator for the sixth an final set in the Rapide Blanc Power-station. In passin it may also be mentioned that the new 40 MVA sy chronous condenser was manufactured by Asea.

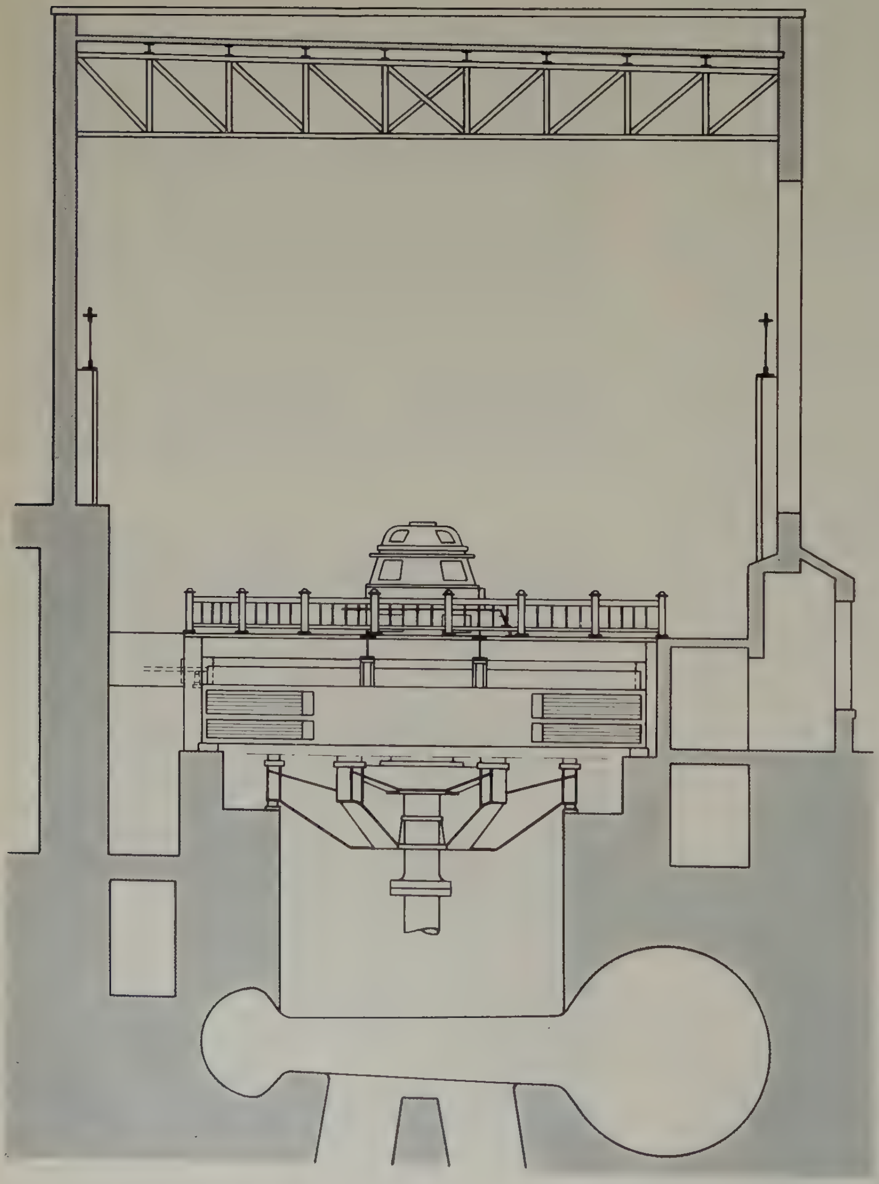


Fig. 1. Elementary drawin showing the Asea generato at the Rapide Blanc Powe station, Canada. (Fr 746)

his will be described in a future number of this journal. he delivery, which was completed in 1955, also inclu-ed a step-up transformer rated at 80/40/40 MVA, 30/11/11 kV for the La Tuque Power-station [see the sea Journal 30[1957]:11–12, p. 161].

HE GENERATOR

he principal data of the machine are as follows:

utput	36 MVA
ower factor	0.85
peed	109 r/m
unaway speed	200 r/m
requency	60 c/s
oltage	11–12 kV
nertia	1,460 tm²

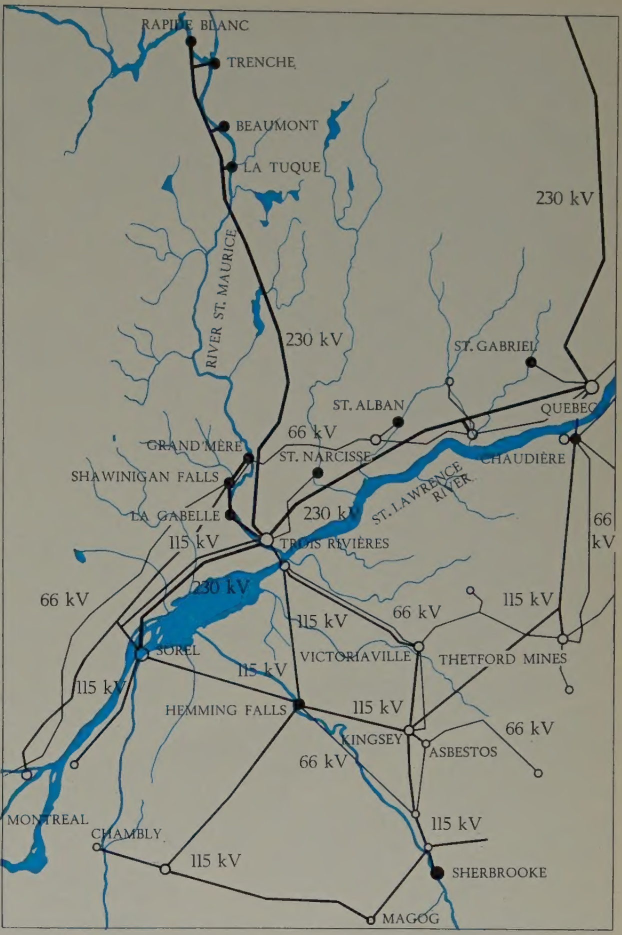
he machine is designed with a combined thrust and uide bearing under the rotor and an upper guide bear-ng. The bearings are of self-pumping type, and two il coolers are provided for the oil-circulation system r the combined thrust and guide bearing. These oolers are located beneath the air intake provided for is generator, but which has not been utilised (to the ight, on Fig. 1). In addition, the generator has a directly oupled permanent-magnet generator, main exciter and uxiliary exciter.

he six brake jacks, which are also employed for rais-ng the rotating parts during erection and overhauls, re operated during braking by compressed air from ne station compressor plant, and during hoisting with il under pressure from a hand-operated pump, which lso serves as a reserve during braking.

he water sprinkler system in the power-station is sed for extinguishing any fire arising in the stator inding. This system does not function automatically the event of a fire, but is operated by hand when real anger is present. The nozzles of the sprinkler tubes will nen spray both coil ends with a dense mist of water.

he rotor is of conventional design with a spider, divided nto two sections, and a rotor rim. Owing to transport mitations, the stacking of the segments for the rim had be done at the power-station. Since space was limited nere, as is always the case with the last set in a power-ation, this work took a comparatively long time. The m was then shrunk on to the rotor spider. The neces-ry heat was obtained by inducing eddy currents in ne rim by means of cables wound around it.

he stator is also of conventional design, being divided to four sections and fitted with eight coolers manu-ctured by AB Svenska Fläktfabriken. The coolers are ranged in pairs around the stator frame and are pable of dissipating 826 kW.



○ Transformer sub-station

● Power-station

Fig. 2. The 230, 115 and 66 kV transmission lines belonging to the Shawinigan Engineering Company. (Fr 745)

The coils, with two groups of conductors per slot, were insulated both inside the slots and at the coil ends with continuous mica tape. The whole assembly was then impregnated repeatedly in a vacuum under pressure with an asphalt compound.

The sheet-metal casing and railings were designed to conform with the appearance of the existing generators in the power-station, see Fig. 3.

When in the workshop, the generator was submitted to normal insulation tests only, since the stacking of the rotor segments was carried out at the site. Standard acceptance tests were performed after the set had been operating under normal service conditions for a few weeks.

When performing the retardation tests and tests with the generator running as a synchronous motor, the turbine was emptied of all water and was then made to rotate in air during the tests. The friction losses in the

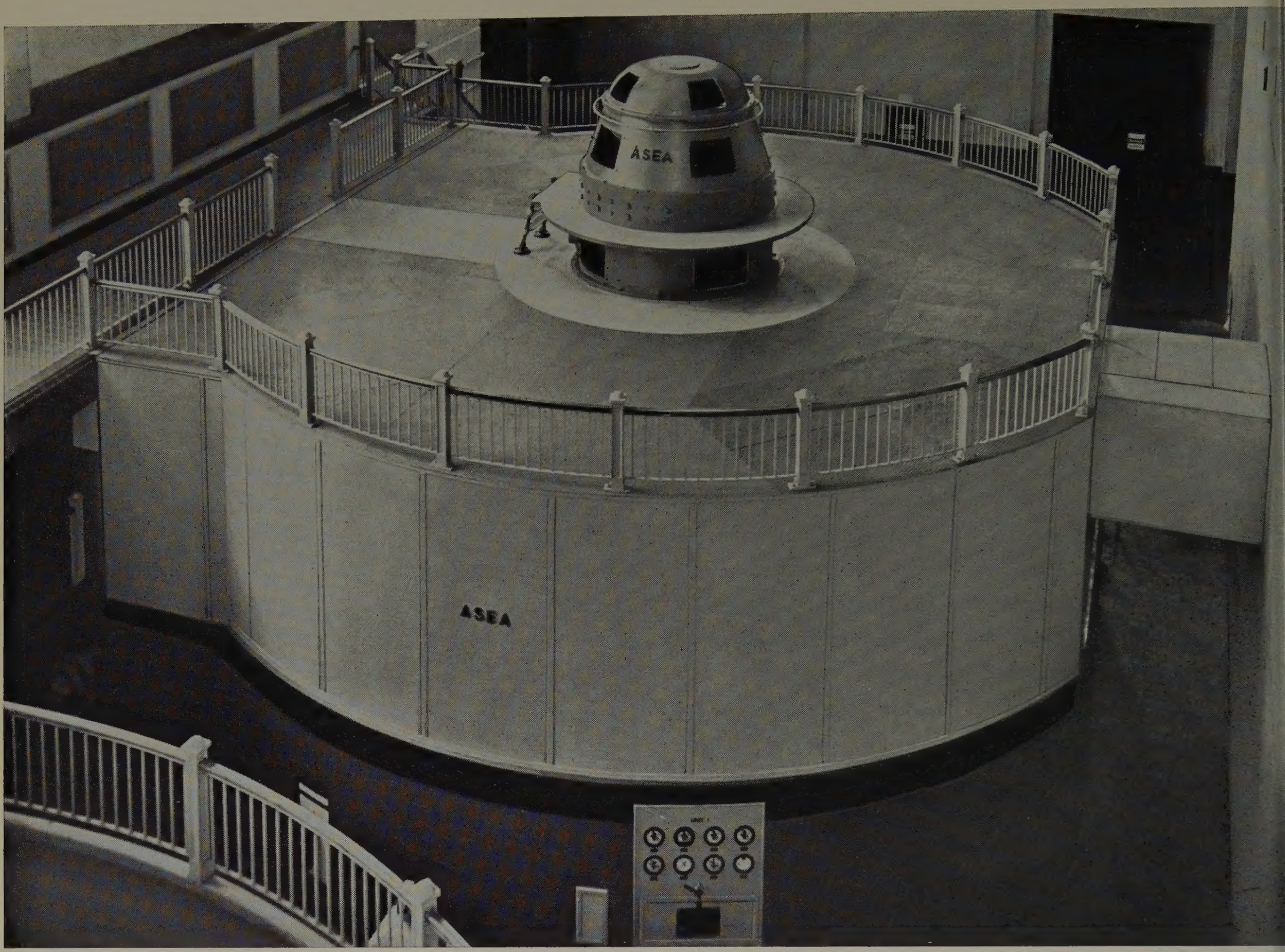


Fig. 3. The 36 MVA generator at Rapide Blanc. The control panel embedded in the concrete wall is intended for the direct supervision of the set. (49324)

turbine are then very small and can be calculated with reasonable accuracy. By adopting such a procedure, the tests are considerably simplified, resulting in a saving of both time and money.

A control panel is mounted flush in the concrete casing for the direct supervision of the set in the machine room itself. This control panel can be seen at the bottom of the photograph in Fig. 3, and contains instruments for the temperature of the thrust bearing, upper guid bearing, lower guide bearing and turbine bearing as we as for the pressure of the thrust-bearing oil, brake and turbine spiral casing. Finally, there is a voltmete for the bearing voltage as a guard against bearing cu rents. The handle for braking can be seen in the middl The control panel also contains the valve for operatin the sprinkler system.

As far as the other control gear is concerned, it can b mentioned that a specially designed protection has bee adopted for short-circuits between turns, which is, i principle, similar to the standard Asea protection.

NEW ASEA DIRECTOR

Ir Alde Nilsson has been appointed
ead of the Asea Production Depart-
ents and Deputy Managing Director
; from 1st January, 1960. He thus
icceeds the late Mr Sven Erik Eriks-
on, whose deputy he became a year
go.

Mr Nilsson, who was born in 1917, joined Asea in 1941, working in the Gothenburg branch from 1943 to 1945 when he took charge of the Örjan Factory at Västerås. In 1952, he was appointed head of the Västerås factories. (Z 11063)

EWS IN BRIEF

SEA DECK CRANES ON BOARD /S BULIMBA

ecently, M/S Bulimba, the first vessel in
series of five cargo liners being built
r the British India Steam Navigation
ompany Limited by Messrs Harland
nd Wolff at their Govan Yard, made
er maiden voyage. M/S Bulimba, which
as a deadweight of 7,234 tons and a
rvice speed of 16 knots, possesses a
umber of unique features, which all
ontribute to flexible service and rapid
rn-rounds in ports. One of the note-
orthy aspects about the cargo-handling
uipment is that it includes five Asea
-ton deck cranes, which are characteri-
d by their excellent spotting ability.

is interesting to observe that the Ward-
eonard regulating system has been adop-
d for all three crane movements. The
eck cranes have a hoisting speed of
31 ft/min (40 m/min), a min. slewing
dius of 15 feet (4.5 metres), a max.
ewing radius of 46 feet (14 metres) and
luffing time of 20 seconds. At the re-
uest of the shipowners, the crane plat-
rm has been extended, but the cabin
r the crane driver is available as a
andard feature for all Asea deck cranes.
eck cranes similar to those on board
/S Bulimba will also be supplied by
sea for the remaining four vessels being
uilt for the B.I.S.N.

nce the deck cranes of the type illus-
ated in the adjacent photograph of the
/S Bulimba were delivered, Asea have
t on to the market a new design,
hich will be described in a future num-
r of the Asea Journal. Asea Reg. 6335

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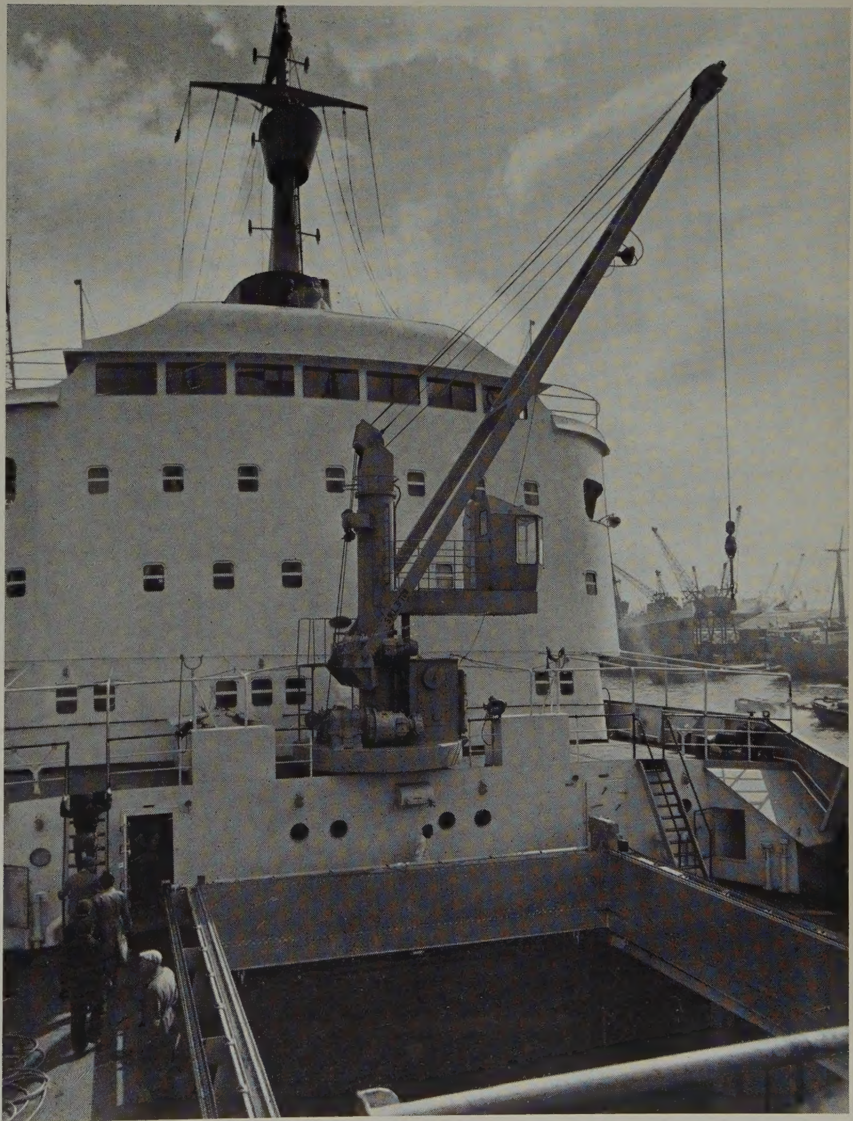

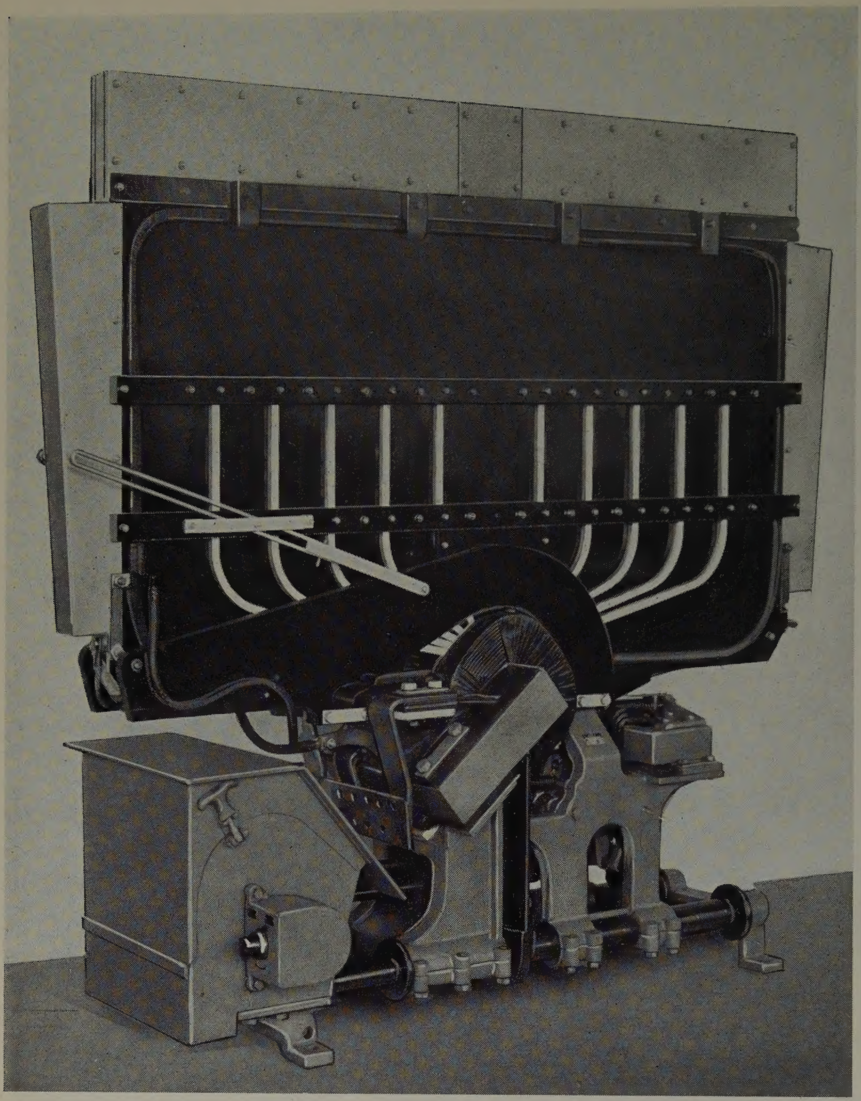

(53140)

NEW HIGH-SPEED CIRCUIT-BREAKER FOR D.C.

The illustration shows a new type of high-speed circuit-breaker (type ASMJF 3/1600) for 3,000 V, 1,600 A, d.c. It has a high breaking capacity and excellent breaking properties. Recently, one of these circuit-breakers successfully withstood a series of severe breaking tests in a converting substation for electric railways in Warsaw. The tests were carried out by the Instytut Elektrotechniki, Warsaw. The Polish State Railways have now ordered fifteen of these circuit-breakers, which are now under manufacture. The first deliveries will be in May, 1960. Asea Reg. 5345

The Asea Journal is published as
monthly review.

All correspondence should be addres
ed to the Editor, Publicity Depar
ment, Asea, Västerås, Sweden.

Articles or extracts from this Journ
may be reprinted on condition th
the name – Asea Journal – is clear
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ASEA JOURNAL

1960 VOLUME 33

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Printed in Sweden Västerås 1960
Västra Aros Tryckeri AB